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The Effect of Interruptions During a Laparoscopy Skills Training Task

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THE EFFECT OF INTERRUPTIONS

DURING A LAPAROSCOPY SKILLS TRAINING TASK

by

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ABSTRACT

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DURING A LAPAROSCOPY SKILLS TRAINING TASK

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The goal of the present study was to examine how interruptions during a laparoscopic skills training task affected task performance. Undergraduate students completed a task that required them to pick up and transfer colored objects in a specific, predetermined sequence. The number of colored objects in the sequence was varied to produce three levels of task demand. During execution of the primary task, participants were interrupted by auditory task-irrelevant communication. The temporal length of interruptions was also manipulated to produce three levels of interruption duration. Results showed that participants made significantly more sequence errors in the high demand condition than in the moderate demand condition. Unexpectedly, a large majority of participants were distracted instead of interrupted by the auditory communication. It was found that distractions did not significantly impair task performance. The general implication of the findings was that the peg transfer task from the Fundamentals of Laparoscopic Surgery is attentionally demanding, particularly when the complexity of the task is increased. However, a non-interruptive auditory dialogue (e.g., communication with trainers or team members) may be time-shared with laparoscopic skills training for novices with minimal impact on performance.

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CHAPTER I

INTRODUCTION

Regardless of the environment, interruptions can pose a threat to focus and performance (Cellier & Eyrolle, 1992; Hess & Detweiler, 1994; Gillie & Broadbent, 1989; Kirmeyer, 1988). Though a minor interruption (i.e., the office phone ringing) may lead to frustration and annoyance (Mark et al., 2008), the effects of disruptive events in high-stakes environments (i.e., aviation, healthcare settings, etc.) may represent greater consequences. For example, interruptions in hospital settings have been shown to increase the frequency of task-related errors. In a study that observed medical workers as they prepared and administered medications, Westbrook et al. (2010) found that for every interruption, the risk of medication error following the disruption increased by an average of 12.7%. Moreover, the researchers found that once a medical worker was interrupted more than six times during their shift, this risk of medication error tripled for every additional interruption.

An *interruption* can be conceptualized as an external stimulus that leads to a temporary pause in a task, prior to its completion, with the intent of completing the respective task (Boehm-Davis et al., 2009). The time course of an interruption is illustrated in Figure 1. As an example, the following section will consider what may happen when an administrative assistant is interrupted while scheduling a meeting.

An assistant is working to find a time slot that will accommodate the majority of the team (the *primary task*), when his/her desk phone begins to ring (the *second task alert*). The time interval between the onset of the alert and the act of answering the phone (the *second task*) is defined as the *interruption lag*. Following completion of the second task, the assistant can then re-engage focus on scheduling the meeting. This interval between the suspension of the second task and the resumption of the primary task is defined as the *resumption lag (*Altman & Trafton, 2004).

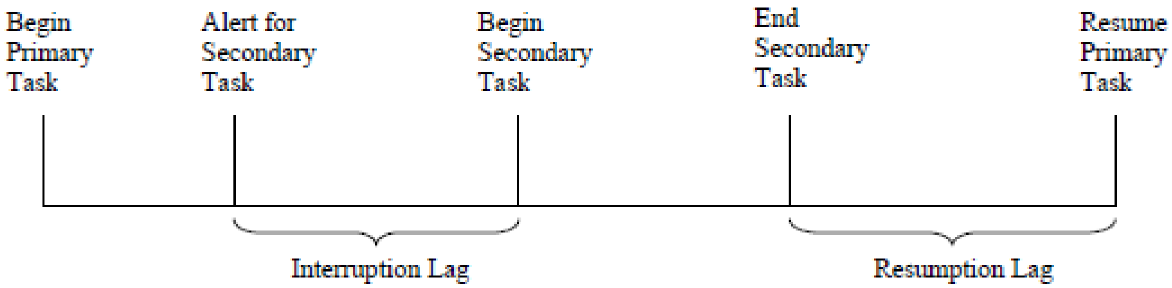

*Figure 1***.** Time-course of an interruption (adapted from Trafton et al., 2003)

Although similar to an interruption, a *distraction* is a stimulus that does not necessarily cause an individual to suspend performance of the primary task (Bourne, 1986; Flynn et al., 1999). Researchers have shown that distractions affect human operators in qualitatively different ways (Bourne, 1986; Flynn et al., 1999). For example, both external (e.g., phone calls) and internal (e.g., fatigue) distractions may tax attentional resources, but they do not force a temporary abdication of the primary task. Though an examination of the effects of both interruptions and distractions would be meaningful, the present study focused solely on the effects of interruptions during a skills-training task because interruptions, when compared to distractions, offer greater experimental control in regard to the manipulation of both temporal duration and attentional demand characteristics.

Temporal Characteristics of Interruptions

Numerous studies have examined the various ways in which interruptions can "hijack" our limited attentional resources while completing tasks. Specifically, researchers have examined the influence of visual (Gulum et al., 2012; Hameed et al., 2009; Latorella, 1998), auditory (Peryer et al., 2005; Sugimoto et al., 1997; van der Lubbe et al., 2005), tactile (Hopp et al., 2006; Hopp et al., 2005) and even olfactory (Arroyo et al., 2002) interruptions on primary task performance.

The research literature has shown that the particular sensory modality of both the interruption and primary task can lead to task performance decrements in different ways. For example, in meta-analysis that investigated interruption alert times (i.e., the time needed to become aware of an interruption; see Figure 1) during ongoing visual tasks, Lu et al. (2003) found that interruption alert processing times differed across sensory modalities. Results showed that participants performing a visual task took longer, on average, to respond to visual interruptions, when compared to auditory interruptions. This finding is consistent with *auditory preemption theory* (Wickens et al., 2005), which posits that the inherently salient nature of auditory stimuli should garner more attention, resulting in shorter alert response times during ongoing visual primary tasks than visual stimuli.

To return to a particular phase of a given task following an interruption, research has shown that the encoding of both internal (e.g., mood) and external (e.g., check-lists) associative cues can help to facilitate reorientation (McFarlane et al., 2002). For example, Field (1987) found that interruptions during tasks that offer external markers of task position (i.e., visual tasks) result in less reduction in performance than tasks that do not offer such cues (i.e., auditory tasks). Additionally, Altmann and Trafton (2002) proposed that individuals might use the brief interruption lag interval to rehearse, in memory, the particular point in the primary task where they were prior to the integration/management of an interruption. To examine this proposal, Hodgets and Jones (2003) had participants complete the five-disc Tower of London problem (Ward et al., 1997), while receiving intermittent verbal-reasoning interruptions. The task required participants to move discs from an initial configuration to a specified "target" arrangement, one disc at a time. The researchers investigated whether task resumption time could be reduced if the interruption was preceded by a brief interruption lag. Their results demonstrated that the insertion of a pause, prior to engagement of the secondary interruption task, significantly reduced the time needed to return to the disc arrangement task. The authors suggested that during the period of interruption lag, the current configuration of the discs was being repeatedly sampled in memory, thus, the resultant activation continued to build which allowed for the encoding of retrieval cues. These findings were some of the earliest to offer evidence of the importance of interruption lag in preparing to resume a delayed task.

Historically, other research has failed to identify any benefits of rehearsal during the period of interruption lag. For example, Miller (2002) investigated how individuals manage interruptions during a team decision-making task. Participants worked to assess the threat level of aircraft that appeared on a simulated radar scope. Additionally, they received intermittent message alerts on their screen that provided further details regarding the various levels of the threat for the aircraft. To read the message (i.e., the secondary task), the participants were required to select the onscreen message by clicking on an icon. The intervals between the secondary task alert and selection of the message (i.e., the interruption lag) and the resumption of the task were of primary interest. To examine the role of rehearsal during the interruption lag interval, participants were assigned to either a rehearsal or non-rehearsal condition. Interestingly, participants who were allowed to rehearse during the interruption lag took significantly longer to return to the primary task (i.e., resumption lag) than those who did not actively rehearse. The authors suggested that these counterintuitive findings may have resulted from participants who failed to use the rehearsal strategy.

In an attempt to make sense of these conflicting findings, Altmann and Trafton (2002) proposed a cohesive theoretical framework, The Activation-Based Goal Memory (AGM) model, for predicting the rate of task resumption following interruption. Their model has been validated in several task-interruption studies (Li et al., 2006; Monk et al., 2004; Trafton, Altmann, Brock, & Mintz, 2003) and serves as a theoretical framework in the current study.

Goal Encoding and Memory Retrieval

The AGM model, derived from the *adaptive control of thought-rational theory* (ACT-R, Anderson et al., 2004), has been used to explain findings from goal encoding and memory retrieval research. The model assumes that a goal's retrieval history and its resultant activation strength affect the ability to recall an encoded goal following interruption. Specifically, the memory "chunk" that is most active during goal-memory retrieval will be returned to working memory (Altmann & Trafton, 2002). Furthermore, for an encoded goal to mediate behavior (i.e., return to a given task following interruption), it has to be strengthened to a level that can overcome the activation threshold set by any retroactive interference from secondary goals (i.e., interruptions).

An additional characteristic of the model is that following task switching, the level of activation for the primary task will begin to decay. As illustrated in Fig. 2, the steep initial incline in activation from repeated sampling of goal-memory is followed by a gradual decline in activation due to an inability to sustain high rates of sampling when engaged in secondary task operations. Importantly, if enough time passes to allow for a significant decay of primary goal memory, the associated level of activation may begin to asymptote. This suggests that secondary tasks (i.e., interruptions) that last longer than the time required for this asymptotic effect to occur will be relatively similar in their impact on primary task goal retrieval. This characteristic of the AGM model can help explain the results from studies that failed to identify any differences in primary task resumption rate following interruptions of various temporal lengths. For example, Gillie and Broadbent (1989) had participants complete a prospective memory task that required the memorization of items from a list. They were then interrupted for either 30 or 165 seconds and had to perform a computer-based task requiring the identification and selection of previously memorized items. The authors did not find any differences in task performance between the two interruption durations and concluded that the temporal length of interruption was not a "critical factor" in whether it would be disruptive. Taking this finding into consideration, the AGM model suggests that no differences were found because the level of activation for the primary task goal had already reached asymptotic levels prior to the "completion" of either of the two interruption durations.

Therefore, researchers must be mindful that interruptions of short and long temporal duration may be relatively similar in their impact on primary task resumption outcomes.

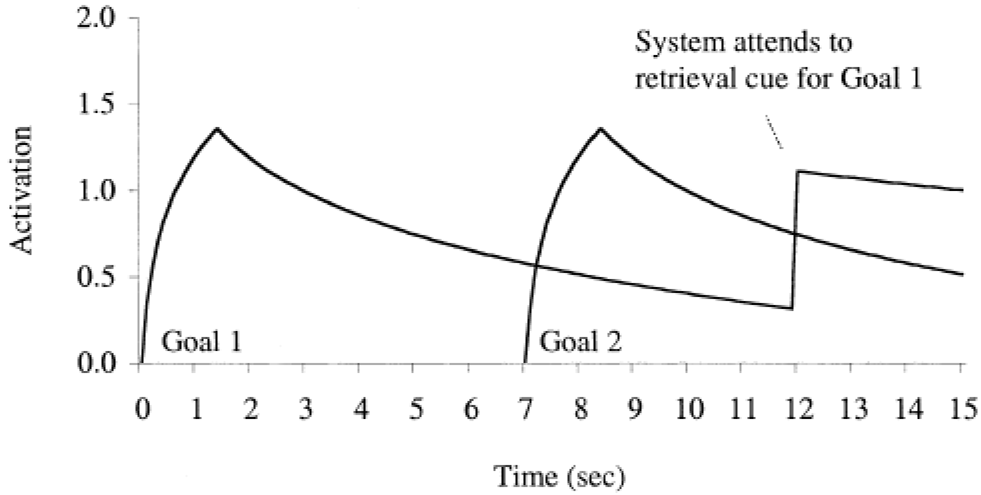

Fig. 2. The effect of time on the level of activation for a task goal. (adapted from Altmann & Trafton, 2002).

Mental Workload and Interruption Cost

Mental workload has been defined as the association between an individual's mental processing capacity and the demands required for a task (Hart & Staveland, 1988). Previous research has shown that the "cost" of an interruption during task completion can be reduced if the interruption occurs during moments of reduced mental workload (Miyata et al., 1986). For example, several studies have identified that the degree to which interruptions impact overall task performance can be attenuated if the interruption occurs in between steps of given task, rather than during execution of the task (Adamczyk and Bailey, 2004; Iqbal et al., 2005; Iqbal et al., 2006). For example, Adamczyk et al. (2004) had participants complete a computer-based task and were interrupted either during task execution or during the transitional period between steps. The authors reported that task performance was significantly better when the interruption occurred in between task steps, when compared with interruptions that occurred during execution of the primary task. The authors suggested that because the participants had just completed the execution of a given task step, the cognitive resources previously allocated to the task were now available to manage a peripheral task (i.e., an interruption).

This finding reflects the Unitary Resource Model (URM; Kahneman, 1973) that proposes that information processing is dependent on the availability of finite cognitive resources. The fundamental premise of the URM is that as the demand of a performed task increases, the amount of available resources will decrease, leaving additional tasks with fewer resources available for use. Specifically, performance on an additional task would be hypothesized to decrease proportionally to the increased demand of the first task (Kahneman, 1973).

Although URM has been used to predict the effects of multitasking in cognition-based research, there is a dearth of literature that has sought to apply the principles of URM to investigate how individuals might manage interruptions during psychomotor tasks. For example, in dynamic complex tasks such as surgery (i.e., a spatial-psychomotor task), several studies have documented the frequency of interruptions (Healey et al., 2007; Weigl et al., 2015); however, few studies have investigated the causal impact of interruptions during surgery (Feuerbacher, 2010; Feuerbacher et al., 2012; Pluyter et al., 2010). Furthermore, no known studies have investigated individual differences in the ability to time-share interruptions under different levels of surgical workload. One form of surgery that tends to be higher in mental workload, when compared to traditional surgery, is laparoscopic surgery.

Laparoscopy

Minimally invasive surgery, also known as laparoscopic surgery, has been developed as an alternative to traditional, open surgery. Generally, laparoscopic procedures involve making small incisions that allow long-handled instruments to be inserted into the body to operate on tissue or organs. To visualize this internal operating cavity, a small camera is also inserted through an incision and projects the image to a nearby video monitor. Due to the reduction in incision size, laparoscopy offers several benefits when compared to traditional surgery. For example, laparoscopy has been shown to improve particular patient outcomes such as overall risk of post-surgical complications (Carbajo, 1999) and recovery times (King et al., 2006). Nevertheless, these benefits to the patient have been accompanied by several challenges for the surgeon. Specifically, several studies have found that laparoscopy results in greater mental fatigue, task-related errors (Miller, 2012), and increased task difficulty (Berguer, 2001) for the surgeon, than traditional surgery. One source of difficulty introduced by laparoscopy is the discrepancy between the visual perception of a traditional three-dimensional operating site and its two-dimensional representation on a video monitor. Shifting from a three-dimensional visualization to a two-dimensional display results in a loss of binocular depth cues. Consequently, this requires the surgeon to rely solely on monocular depth cues which may lead to reduced surgical performance, longer operation times, and increased mental fatigue (Cuschieri, 2006; Tendick, 1997; Way et al., 2003). Therefore, the additional workload demands of laparoscopy may be increasingly susceptible to the deleterious effects of interruptions.

Goals of this Research

Although a few studies have examined the effects of interruptions during traditional surgery training (Feuerbacher, 2010; Feuerbacher et al., 2012; Pluyter et al., 2010), the current study is the first to examine these effects in a minimally invasive surgery-training task. Predictions regarding the impact of interruptions on surgical performance were based on Kahneman's Unitary Resource Model (1973) and Altmann's Activation-Based Goal Memory (2002) models.

URM suggests that managing an interruption during surgery could lead to a decrease in the amount of attentional resources available for concurrent execution of the primary surgical task. Furthermore, if the primary task was particularly demanding prior to interruption, URM would predict greater decrements in task performance, compared to less demanding tasks. Therefore, the goal of this investigation was to examine if manipulating the task demand would lead to differential decrements in task performance following interruption.

If an individual is interrupted while completing a task, the AGM model suggests that interruptions that are longer in duration will lead to an increased amount of memory decay for the primary task goal. Consequently, the AGM model would predict that longer interruptions would increase the amount of time needed to return to the primary task (i.e., resumption lag). Therefore, the current study also sought to examine if manipulating the temporal length of interruptions during primary task execution would lead to different task resumption times.

CHAPTER II

PRESENT STUDY

In the present study, undergraduate students completed a laparoscopic skills training task that required them to pick up and transfer colored objects in a specific, predetermined sequence. The number of colored objects in the sequence varied to produce different levels of task demand. Additionally, during execution of the primary task, participants were interrupted by auditory task-irrelevant communications. In an effort to bolster ecological validity, this type of interruption was selected because a prior meta-analysis of surgical interruption research by Yoong and colleagues (2015) found that task-irrelevant communication accounted for nearly twenty-five percent of all operating room interruptions.

The current study employed a 3x3 split-plot design. The within-subjects factor was interruption duration and had three levels: no-interruption control (zero duration), short (10-20) seconds), and long (30-40 seconds). The between-subjects factor was task demand and had three levels: low (one color), medium (three colors), and high (six colors). The primary measures of interest were transfer sequence errors (i.e., a ring transferred in the incorrect sequence) and resumption lag (i.e., the time interval between concluding the interruption and returning to execution of the task). The current study had three primary hypotheses.

As suggested by Kahneman (1973), individuals have limited attentional resources to divide among concurrent tasks. If interrupted while completing a highly demanding task, URM predicts that the attentional resource demand would exceed the operator's available cognitive capacity. Consequently, it was hypothesized that primary task performance decrements—in the form of transfer sequence errors—would result from insufficient attention. Therefore, it was predicted that the three task demand groups would differ significantly in the number of transfer sequence errors, due to a reduction in availability of attentional resources following the management of a secondary task (i.e., an interruption). Specifically, it was predicted that significantly more errors would be made for the high demand condition, compared to moderate and low demand conditions.

The second hypothesis is based on Altmann and Trafton's AGM model (2002). Specifically, the longer the primary task goal decays in memory following an interruption, the longer it will take to resume the respective task. Therefore, it was predicted that the three interruption duration conditions would differentially impact resumption lag times due to differences in task goal memory decay following the onset of an interruption. Specifically, it was predicted that participants in the long duration condition would experience the longest resumption lags. Finally, it was predicted that interruptions and task demand would interact such that increasing the temporal length of an interruption would lead to greater decrements in task performance when the task demand was high, compared to low and medium task demands.

CHAPTER III

METHOD

Participants

To determine an appropriate sample size for the current study, a power analysis was conducted in using the G*Power software (Version 3.0.10). With a dearth of similar experimental literature available to suggest an appropriate effect size, a general power analysis was conducted to detect a medium effect (partial $\eta^2 = .15$) with $\alpha = .05$ and power = .80. The results suggested a sample size of 58. A total of 59 participants was recruited from undergraduate psychology classes. All participants were at least 18 years of age, with a mean age of 22. Forty participants were female (68%) and nineteen were male (32%). All participants had normal or corrected-to-normal vision. All participants provided written informed consent and this study was approved by the Institutional Review Board at Old Dominion University.

Primary Task

The primary task was the peg transfer task from the Fundamentals of Laparoscopic Surgery (FLS) training and assessment module. The FLS modules (www.flsprogram.org) provide the opportunity to acquire and refine fundamental laparoscopic skills such as eye-hand coordination using simulated psychomotor tasks. To begin, participants hold a laparoscopic grasper in each hand and use the grasper in their *non-dominant* hand to pick up a ring of choice (see Figure 4), transfer the ring in midair to the grasper in their *dominant* hand, and finally place the rubber ring on a plastic peg.

The participants were required to follow this process until all rubber rings had been transferred to their respective pegs on the opposite side of the board.

Figure 4. Peg Transfer Task. Participants use the laparoscopy graspers to pick up and transfer a colored ring from one side of the board to a corresponding peg on the other side.

Task Demand

Prior to beginning the primary transfer task, participants were briefly shown a document that displayed a sequence in which the colored rings were to be transferred (see Figure 5). To manipulate the demand of the primary task, the presented sequences varied in the number of colors that were to be memorized. For example, all six rings in the low demand condition were the same color, while each ring in the high demand condition was a different color. Participants were assigned at random to one of three task demand conditions: low, medium, or high. This task demand manipulation was chosen because prior research by Luck and Vogel (1997) has shown that the capacity of visuospatial working memory is approximately 3-4 items. Therefore, it was predicted that exceeding this available capacity would result in transfer sequence errors. This prediction was subsequently confirmed via pilot testing.

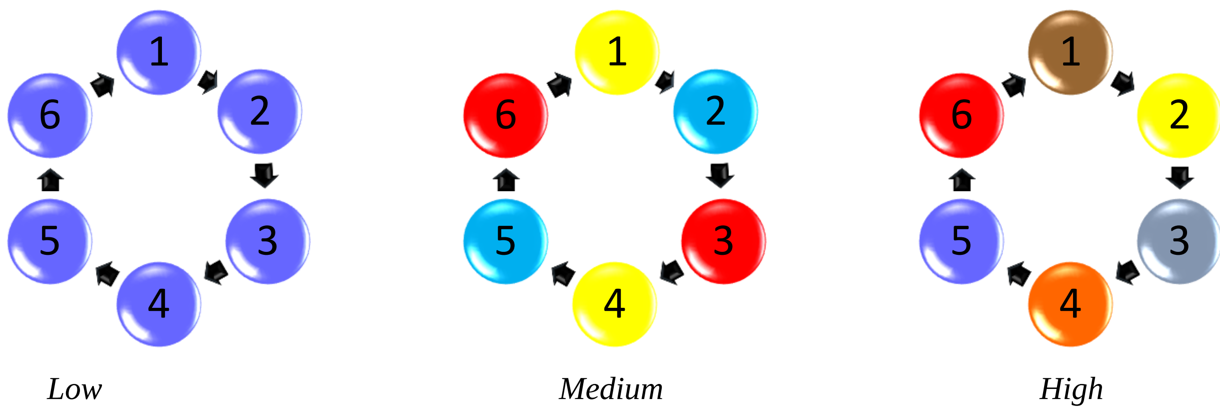

Figure 5. Ring placement sequence and level of task demand. Participants were shown one sequence prior to the beginning of each task block.

Task Interruptions

Participants were unexpectedly interrupted during completion of the primary task. The interruptions varied in temporal duration and had three levels: short, long, and a no-interruption control. The duration of interruptions was derived from the findings of

Altman and Trafton (2002) regarding the asymptotic activation for task goal-memory. Specifically, the short interruption lasted 10-20 seconds and the long interruption lasted 30-40 seconds. Based on the findings of Yoong and colleagues (2015), auditory task-irrelevant communication interruptions were used. Pilot testing found that this communication interrupted execution of the primary peg transfer task. Visual interruptions were not examined in the present study because pilot testing found no significant differences in the number of sequence transfer errors, when compared to auditory interruptions.

Participants were interrupted once, immediately following the placement of the first ring in the color sequence. This point was chosen so that the participant would have minimal time to rehearse the color sequence in working memory. The participant was not interrupted immediately after being shown the color-sequence so that the level of activation would have some time to build.

For the short interruption, participants were asked why they chose to sign up for the current study. Alternatively, for the long interruption, participants were asked why they had decided to enroll at Old Dominion University and what major they were currently pursuing. These two interruptions were selected after pilot testing indicated that they had achieved the desired temporal lengths. To control the predetermined temporal ranges of the interruptions (i.e., 10-20 or 30-40 seconds), a digital clock was placed in sight of the research assistant. The research assistant was trained to naturally continue or cease the dialogue as needed. For example, if the participant finished responding to the interruptive question prior to reaching the desired temporal length, the research assistant would ask for further elaboration on their response. Alternatively, if the participant took too long to provide a response, the research assistant would politely ask him or her to continue the task.

Material and Equipment

A laparoscopic training box was utilized for the primary task. The dimensions of the plastic training box were 42 cm x 36 cm x 25 cm. The task was performed with two Johnson & Johnson Ethicon™ graspers, a pegboard, and a set of six individually colored rubber rings. A Logitech C910 HD 1080p video camera was affixed to the interior ceiling of the training box and was used to project the task field inside of the box to an Alienware OPTX AW2210 monitor placed on top of the box (Figure 6). Additionally, a Nikon D3200 camera was used to record task performance.

Figure 6. Laparoscopic training box.

Subjective Measures

As a manipulation check regarding primary task demand, participants were asked to rate their perceived workload via the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988). The NASA-TLX (see Appendix C) allowed participants to report their subjective levels of mental demand, physical demand, temporal demand, performance, effort, and frustration for each task workload condition. Participants were required to indicate their scores on an interval scale with values ranging from 1 to 20. The NASA-TLX has been shown to have internal, convergent, and concurrent validity (Rubio et al., 2004), along with high levels of test/re-test reliability (Hart et al., 1988). Furthermore, the NASA-TLX has been shown to be sensitive to changes in perceived workload during surgery (Yurko et al., 2010).

Procedure

Participants first read and signed an informed consent form (see Appendix A). To begin, participants were given ten minutes to practice the peg transfer task, during which they could ask questions and gain familiarity with the procedure. After the practice session, participants no longer received feedback regarding their performance. Prior to beginning each task block, participants were presented with a ring transfer color sequence that corresponded to the order in which the six, colored rings were to be transferred. Specifically, the research assistant held up a document that displayed the sequence for six seconds (i.e., one second per ring). Next, the participants began the peg transfer task and continued until all six rings were transferred to their corresponding pegs. If a rubber ring fell out of camera view, participants were asked to terminate the process for the current ring and to proceed to the next ring in the sequence. For the interruption conditions, participants were interrupted once, immediately following the placement of the first ring in the sequence. Following completion of each task block, the participant completed a NASA-TLX questionnaire. Following completion of the three task blocks, participants were debriefed and thanked for their time. Each session took approximately thirty minutes.

CHAPTER IV

RESULTS

Of the 59 undergraduate students who participated, 8 participants did not respond to either the short or long duration task irrelevant communication. Their data were excluded from the analysis leaving a total of 51 participants. Contrary to the findings from pilot testing, a large majority of participants (n=46) were not interrupted by the task irrelevant communication, but were instead distracted. Specifically, these distracted participants continued execution of the primary peg transfer task while responding to the questions from the researcher. Therefore, the second hypothesis predicting differences in resumption lag could not be examined. Additionally, participants in the low task demand condition were excluded from the analysis, as it was not possible to make sequence errors due to the single ring color. Descriptive statistics for sequence errors and mental workload scores for the five participants that were interrupted can be found in Tables 1 and 2.

Interrupted Task Performance Results

Sequence Errors. On average, each participant made 1.10 sequence errors per trial when interrupted. Results from a descriptive statistics analysis indicate that individuals in the high task demand condition made more sequence errors than those in the moderate demand condition per trial on average (see Table 1).

Table 1
Descriptive Statistics for Sequence Errors by Task Demand and Interruption Duration

		Mean	SD	n
High				
	No	0.67	1.15	3
	Short	2.67	2.32	3
	Long	0.67	1.15	3
Moderate				
	No	0.00	0.00	2
	Short	2.00	2.83	2
	Long	0.00	0.00	2

Duration of Interruption. Results from a descriptive statistics analysis indicate that the long duration interruption was longer than the moderate duration interruption condition, per trial on average (see Table 2).

Table 2
Descriptive Statistics for Length of Interruption by Duration and Demand

		Mean	SD	n
Short				
	High	15.33	1.53	3
	Moderate	12.00	1.41	2
	Low	15.00	0.00	1
	Total	14.17	2.04	6
Long				
	High	30.00	8.72	3
	Moderate	19.00	5.66	2
	Low	25.00	0.00	1
	Total	25.50	8.12	6

Rings Transferred During Interruption. Results from a descriptive statistics analysis indicate that the number of rings transferred during both the long duration interruption and short duration interruption condition were equivalent. Specifically, participants did not transfer any rings during the interruption interval. This finding was expected because genuine interruptions should lead to a temporary abdication of primary task execution.

Distracted Task Performance Results

To assess performance for the participants who were distracted during the peg-transfer primary task, a 2 Demand (medium, high) x 3 Distraction (short, long, none) split-plot ANOVA was performed. Pairwise comparisons of the mean differences were analyzed with Bonferroni-corrected degrees of freedom. Statistical significance for all data was assessed at the .05 significance level unless otherwise noted.

Table 3
Results of the Analysis of Variance for Sequence Errors by Demand and Distraction Duration

	SS	df	MS	*F*	*p*	partial η^2
Demand	11.58	1	11.58	10.54	.003*	.281
Error	29.68	27	1.09			
Duration	0.92	2	0.46	0.43	.654	.016
Demand x Duration	1.38	2	0.69	0.64	.530	.023
Error	57.78	54	1.07			

Note. * $p < .05$

Sequence Errors. An ANOVA was performed to assess the difference in number of sequence errors for the primary peg transfer task between the levels of task demand and the duration of the distraction. The results from the analysis can be seen in Table 3.

The analysis revealed a main effect of task demand on peg-transfer sequence errors. Post hoc comparisons indicated that significantly more errors were made in the high task demand condition than in the moderate task demand condition, F (1, 27) = 10.54, p = .003, η^2 = .281.

Table 4
Means, Standard Errors, and Confidence Intervals for Sequence Errors by Demand and Duration

		Mean	Std. Error	95% Confidence Interval	
				Lower	Upper
High					
	No	1.14	0.31	0.50	1.78
	Short	1.07	0.23	0.59	1.55
	Long	0.64	0.28	0.06	1.22
	Total	0.95*	0.16	0.62	1.28
Moderate					
	No	0.27	0.30	-0.35	0.88
	Short	0.13	0.23	-0.33	0.59
	Long	0.27	0.27	-0.29	0.83
	Total	0.22*	0.16	-0.09	0.54

*Note: * indicates significantly different means.*

Length of Distraction. With the experimental design allowing for variation in the length of task-irrelevant communication, an ANOVA was performed to assess whether the temporal length of distractions were significantly different between the duration conditions. The results from the analysis can be seen in Table 5.

Table 5
Results of the Analysis of Variance for Length of Distraction by Duration and Demand

	SS	df	MS	*F*	*P*	partial η^2
Demand	601.12	2	300.56	2.17	.127	.092
Error	5967.46	43	138.78			
Duration	10826.84	1	10826.84	137.62	.000*	.762
Demand x Duration	57.24	2	28.621	0.36	.697	.017
Error	3382.97	43	68.67			

Note. * $p < .05$

Length of Distraction Results. The analysis revealed a main effect of distraction duration. Post hoc comparisons indicated that distractions were significantly longer in the long duration condition than in the short duration condition (see Table 6).

Table 6
Descriptive Statistics for Length of Distraction by Duration and Demand

		Mean	SD	n
Short				
	High	15.64	6.61	14
	Moderate	15.20	6.11	15
	Low	19.29	6.44	17
	Total	16.85*	6.44	46
Long				
	High	35.43	11.13	14
	Moderate	37.07	11.88	15
	Low	42.94	15.93	17
	Total	38.74*	13.45	46

*Note: * indicates significantly different means.*

Rings Transferred During Distraction. With a longer temporal interval for primary task execution, it would be expected that more rings would be transferred during the longer distraction condition. An ANOVA was performed to examine if the number of rings transferred were different across conditions. The results from the analysis can be seen in Table 7.

Table 7

Results of the Analysis of Variance for Rings Transferred when Distracted

	SS	df	MS	*F*	*P*	partial η^2
Demand	7.09	2	3.55	6.12	.005*	.221
Error	24.92	43	0.58			
Duration	17.89	1	17.89	55.79	.000*	.565
Demand x Duration	1.12	2	0.56	1.75	.187	.075
Error	13.79	43	0.32			

Note. * $p < .05$

Rings Transferred During Distraction Results. The analysis revealed a significant main effect of task demand on the number of rings transferred when distracted, F (2, 43) = 6.12, p = .005, η^2 = .221. Post hoc comparisons indicated that significantly more rings were transferred in the low demand condition (M=1.43, SE=0.13), when compared to the high demand condition (M=0.77, SE=0.14), per trial on average. The moderate demand condition (M=0.98, SE=0.14) did not significantly differ in rings transferred from the low or high demand conditions. Additionally, the analysis revealed a main effect of distraction duration on the number of rings transferred when distracted. As would be expected, post hoc comparisons indicated that significantly more rings were transferred during the long distraction condition (M=0.62, SE=0.08), when compared to the short distraction condition (M=1.50, SE=0.12).

Manipulation Check

An ANOVA was conducted to assess global workload scores under different levels of task demand and distraction duration. The results from the analysis can be seen in Table 8. As can be seen in the table, none of the variables were statistically significant for global workload.

Table 8
Results of the Analysis of Variance for Global Workload Scores when Distracted

	SS	df	MS	*F*	*P*	partial η^2
Demand	5822.13	2	2911.06	2.45	.097	.103
Error	50693.61	43	1178.92			
Duration	600.60	2	300.03	2.61	.079	.057
Demand x Duration	783.03	4	195.76	1.70	.156	.073
Error	9878.06	86	114.86			

Note. * $p < .05$

Manipulation Check Results. Subsidiary analyses indicated that the mental demand subscale scores were significantly greater in the high task demand condition (M=12.00), when compared to the moderate (M=8.02) and low task demand (M=8.28) conditions, F (2, 43) = 3.39, p = .043, η^2 = .143.

Additionally, descriptive statistics for global workload scores were calculated for the five participants who were interrupted (see Table 9). Similar to the results from the distracted participants, subsidiary analysis revealed a trend whereby the mental demand subscale scores were greater for the high task demand (M=14.22), when compared to the moderate (M=6.50) and low task demand (M=10.00) conditions,

Table 9

Descriptive Statistics for Global Workload by Interruption Duration and Demand

		Mean	SD	n
No				
	High	58.67	24.95	3
	Moderate	39.50	10.61	2
	Low	35.00	0.00	1
	Total	48.33	20.06	6
Short				
	High	66.00	26.21	3
	Moderate	37.50	6.36	2
	Low	40.00	0.00	1
	Total	52.17	22.66	6
Long				
	High	61.33	14.57	3
	Moderate	58.50	20.51	2
	Low	43.00	0.00	1
	Total	57.33	14.84	6

Chapter V

DISCUSSION

The purpose of the present study was to investigate the effects of interruptions on performance of a laparoscopic skills-training task. Participants were unexpectedly interrupted for varying lengths of time at specific, predetermined points during execution of a psychomotor task that varied in mental demand.

Interruptions and Distractions

Although interruptions and distractions are similar, their effects on human information processing are qualitatively different. Both may tax attentional resources, but an interruption produces a temporary pause in a task prior to its completion, whereas a distraction does not necessarily force suspension of the task. Additionally, a critical feature of interruptions is that the goal memory for the temporarily suspended task will begin to decay in working memory (Altmann and Trafton, 2002). To return to the task following interruption, the associated level of activation for the goal must overcome any retroactive interference from the interruption. Prior research conducted by Altmann and Trafton (2002) has generally shown that the longer an interruption, the longer it takes for the individual to resume the interrupted task. Although a primary goal for the present study was to examine if this relationship between memory decay and task resumption generalized to a visuospatial task, this hypothesis could not be tested. The original plan was to interrupt participants during execution of the primary task, but a large majority (n=46) treated the interruption (an auditory communication from the researcher) as a distraction. This was not expected as pilot testing showed that the auditory communication interrupted all participants (n=6) during execution of the task.

In general, the participants who were interrupted in the present study committed more errors when the mental demand of the task was high than when it was moderate. Furthermore, as would be expected, participants temporarily ceased execution of the primary task when interrupted. Consequently, the following sections will discuss the findings for participants who were distracted.

Primary Task

It was predicted that primary task performance would be poorer for the high demand group compared to the moderate and low demand groups, possibly indicating that fewer attentional resources were available for execution of the peg transfer task. This hypothesis was supported. Participants committed significantly more sequence errors in the high demand condition than in the moderate demand condition. Furthermore, when distracted, participants transferred significantly fewer rings in the high demand condition than in the moderate and low demand conditions. The reported NASA-TLX scores partially corroborate these findings. Although there were no effects observed on the global workload scores, a subsidiary analysis of the subscales indicated that participants in the high demand condition reported significantly greater perceived mental demand, when compared to the moderate and low demand conditions.

This reduction in performance as the demand of the task increased could be due to the requirements for the high demand condition exceeding the participant’s visuospatial working memory capacity. For example, prior to beginning the primary transfer task, participants were briefly shown a document that displayed a sequence in which the colored rings were to be transferred. The moderate demand group had to remember the order of three pairs of colored rings, while in the high demand condition each ring was a different color requiring these participants to retain the order of six rings in memory. This strain on visuospatial working memory capacity for the high demand group could have led to a decrement in task performance.

It was also predicted that the longer the primary task goal is held in working memory and subject to decay following an interruption, the longer it will take to resume the respective task. However, because most participants treated the auditory communication as a distraction and not an interruption, there was no way to measure resumption lag.

It was also hypothesized that the length of the intended interruption and task demand would interact such that increasing the temporal length of the interruption would lead to greater decrements in task performance when the task demand was high, compared to low and moderate task demands. This hypothesis was not supported because the intended interruptions were in fact distractions. The number of sequence errors committed did not depend on distraction duration. This lack of evidence for an effect of distraction length on task performance decrement could be due to sufficient attentional resources being available for use. Specifically, it may be possible that the amount of attentional resources needed to remember the ring sequence was low enough that an additional task (i.e., listening and responding to a distraction) could be timeshared with no significant reduction in performance.

Theoretical Implications

Overall, the findings are consistent with the Unitary Resource Model (URM; Kahneman, 1973), which proposes that information processing is dependent on the availability of finite cognitive resources. The fundamental premise of the URM is that as the demand of a task increases, the amount of available resources will decrease, leaving additional tasks with fewer resources available for use. This is precisely what was found in terms of task demand in the present study. Specifically, as the demand of the ring transfer task increased, fewer rings were transferred during intervals of distraction. This suggests, as expected, that the attentional resources required to listen and communicate with the researcher (i.e., the distraction) altered the amount of resources previously allocated solely to the primary ring transfer task.

The differences observed for ring transfer are also consistent with *Multiple Resource Theory* (MRT; Wickens, 1980), which has been used as a theoretical framework to guide predictions of attentional resource allocation among concurrently executed tasks. The essential premise of MRT is that there are several "pools" of attentional resources that are reserved for different sensory modalities (e.g., visual vs. auditory), stages of processing (perception vs. cognition vs. responding), and codes of processing (e.g., spatial vs. verbal). Specifically, if task demands are similar (i.e., visual task with visual distractions), the tasks may utilize the same pool of attentional resources; thereby, increasing the operator's mental workload, and decreasing time-sharing performance. The overall level of errors in the high demand (M= 0.95) and moderate demand conditions (M=0.22), may be relatively low because the two tasks were very different in regard to their sensory modalities (i.e., visual vs auditory), stage of processing (i.e., cognition vs. responding), and code of processing (i.e., spatial vs. verbal). This high differentiation may have allowed participants to execute the task without an extensive strain on attentional demand.

Additionally, the findings of the present study are consistent with the prior research on visuospatial working memory capacity from Luck and Vogel (1997). Specifically, the present study found that significantly more sequence errors were made in the high demand condition (i.e., six colors), when compared to the moderate demand condition (i.e., three colors). Therefore, it is possible that more errors were made because participants exceeded the 3 to 4 item short-term memory capacity previously documented by Luck and Vogel (1997).

Although the Activation-Based Goal Memory (AGM; Altmann & Trafton, 2002) model has been used to explain findings from goal encoding and memory retrieval research, it is intended to predict the effects of genuine interruptions. Therefore, because the present study primarily investigated the effects of distractions on task performance, the predictions of the AGM model were not applicable. Specifically, because distractions do not necessitate task goals to be held in working memory during suspension of a task, predictions regarding memory retrieval are not relevant. A descriptive statistics analysis for the six participants who were interrupted showed that it took longer to resume the task following a longer interruption (M=16.20 seconds, SD= 6.83) compared to a short interruption (M=13.60, SD= 7.83).

Limitations

An unanticipated limitation in the present study was that only 10% of the participants were interrupted by the task-irrelevant communication, while 90% of participants were instead distracted. As a result, the present study was unable to examine the dependent variable of resumption lag. This was not expected as pilot testing found that all participants were interrupted by the communication.

In regard to the short- and long-duration dialogue between the participants and the researcher (i.e., the distraction conditions), there may not have been enough of a difference in temporal length for an effect on task performance to manifest itself. Although the predetermined temporal ranges for the short (10-20 seconds) and long (30-40 seconds) distractions were consistent with the observed short ($M=16.86$ seconds, $SD= 6.44$) and long ($M=38.74$ seconds, $SD= 13.45$) distractions, they may still be too similar in terms of their effect on human information processing.

Another limitation is that participants may not have received enough training prior to beginning the three blocks of the primary peg transfer task. Though ten minutes was provided to gain familiarity with the physical aspect of the task (i.e., manipulating the graspers to move rings), there was no training that allowed participants to gain familiarity with remembering a ring transfer sequence. The decision to not provide training with the color sequence was based on the idea that early exposure to the sequence (i.e., during the training session) might increase familiarity with the procedure thereby limiting its effectiveness during the actual task.

Practical Implications

The general practical implication of the findings was that the peg transfer task from the Fundamentals of Laparoscopic Surgery is attentionally demanding, particularly when the complexity of the task is increased. Additionally, it was found that distractions did not significantly impair novice performance during a fundamental laparoscopic skills training task. This finding suggests that a non-interruptive auditory dialogue (e.g., communication with trainers or team members) may be amenable to time-sharing during laparoscopic skills training among novices.

Future Work

Several changes could be made to improve the methods used in the present study. Auditory-based communication can lead to either a distraction or interruption depending on the individual and their current state. A modification that could be made to remedy this limitation observed in the present study would be to substitute visual interruptions for auditory interruptions. This change would allow for the pegboard and graspers displayed on the monitor to be occluded (e.g., a temporarily blacked-out screen) for a predetermined interval of time. This occlusion would serve as a genuine interruption to the execution of the primary ring transfer task. Additionally, using a visual interruption would allow for control over the exact interval of interruption, something that was not possible with auditory interruptions.

Another change that could improve the methods in the present study would be to decrease the temporal length of the short duration distraction. While the present study did not originally seek to investigate the effect of distractions on task performance, it may be meaningful to further examine the impact of short and long distractions. A possible reason that the present study did not find a significant effect of distraction duration on task performance may be that the short and long distractions were qualitatively similar in terms of their impact on attentional demand.

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APPENDIX A

INFORMED CONSENT FORM

PROJECT TITLE: Attentional Resource Allocation: An Examination of Competing Cognitive Processes

RESEARCHERS:

Mark W. Scerbo, Ph.D., Responsible Project Investigator, Professor, College of Sciences, Psychology Department

Co-investigators:

Brandon Fluegel, Graduate Student, College of Sciences, Psychology Department

DESCRIPTION OF RESEARCH STUDY

Laparoscopic surgery is a type of surgery that is performed by inserting a small camera and surgical instruments through small incisions in the body. This technique is generally safer for the patient, but often more difficult for the surgeon to perform. Therefore, computer-based simulators are now being used to help surgeons acquire laparoscopic skills.

If you decide to participate, then you will be one of approximately 80 undergraduate students involved in a study designed to improve current methods for training future laparoscopic surgeons using a computer-based simulator. You will be instructed in how to perform several simulated surgical tasks on the computer using simulated surgical tools and a foot pedal and then given time to practice those tasks. Afterward, you will also be asked to complete two brief questionnaires that ask you to rate the ease or difficulty of the tasks. The total amount of time for participation is approximately one hour.

EXCLUSIONARY CRITERIA:

To participate in this study, you must be an undergraduate student at ODU. You must be 18 years of age or older. You also must have normal or corrected-to-normal vision. If you wear contacts or glasses, you must have these with you when you participate

In addition, in order to participate in this study you should not have any problems with your ability to physically use your right leg and right foot to press a foot pedal periodically. You should also not have any problem physically using both your right and left hands to interact with the simulated surgical instruments

RISKS:

If you decide to participate in this study, then you may face a risk of slight physical fatigue. Both your arms and hands may become tired from interacting with the simulator instrument device. The researchers have tried to reduce these risks by incorporating frequent breaks and resting periods. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS:

There are no direct benefits for participation. However, you will have the opportunity to learn how a surgical simulator is used for developing basic laparoscopic skills.

COSTS AND PAYMENTS:

If you decide to participate in the study, you will receive 1 Psychology department research credit, which may be applied to course requirements or extra credit in certain Psychology courses. Equivalent credits may be obtained in other ways, such as conducting library reports and online surveys. You do not have to participate in this study, or any Psychology Department study, in order to obtain this credit.

CONFIDENTIALITY:

The researchers will take reasonable steps to keep private information, such as questionnaires and laboratory performance and findings confidential. The researchers will remove all identifying information from questionnaires and store all data in a locked filing cabinet prior to its processing. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE:

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study – at any time. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation. If at any point during the study you wish to stop, simply tell the researcher and you will not be penalized in any way. Any data that has already been collected will be destroyed and will not be included in the final analysis.

COMPENSATION FOR ILLNESS AND INJURY:

If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of injury, or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in any research project, you may contact the Faculty research advisor, and responsible principle investigator Dr. Mark W. Scerbo at 757-683-4217 or Dr. George Maihafer the current IRB chair at 757-683-4520 at Old Dominion University, who will be glad to review the matter with you.

VOLUNTARY CONSENT:

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

Dr. Mark W. Scerbo, mscerbo@odu.edu, (757) 683-4217

Brandon Fluegel, bflue001@odu.edu, (508) 971-5520

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. George Maihafer, the current IRB chair, at (757) 683-4520, or the Old Dominion University Office of Research, at 757-683-3460.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

------------------------------------ ----------------------------------

Participant’s Name Participant’s Signature Date

INVESTIGATOR’S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

------------------------------------ ----------------------------------

Investigator’s Name Investigator’s Signature Date

APPENDIX B

PARTICIPANT BACKGROUND INFORMATION FORM

Participant #:_____ Group:_____ Date:_____ Time:_____

The purpose of this questionnaire is to obtain background information on the participant that will be used for research purposes only.

1. Age______

2. Gender______

   0 = Female

   1 = Male

3. Do you have normal or corrected-to-normal vision?_____

   0 = Yes

   1 = No

4. What is your dominant hand?_____

   0 = Right

   1 = Left

   2 = Ambidextrous

5. Do you play video games?_____

   0 = Yes

   1 = No

   If yes: how many hours, on average, do you play each week?____

APPENDIX C

NASA-TASK LOAD INDEX (TLX) WORKLOAD QUESTIONNAIRE

(Hart & Staveland, 1988)

MENTAL DEMAND

Low High

| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

PHYSICAL DEMAND

Low High

| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

TEMPORAL DEMAND

Low High

| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

PERFORMANCE

Low High

| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

EFFORT

Low High

| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

FRUSTRATION

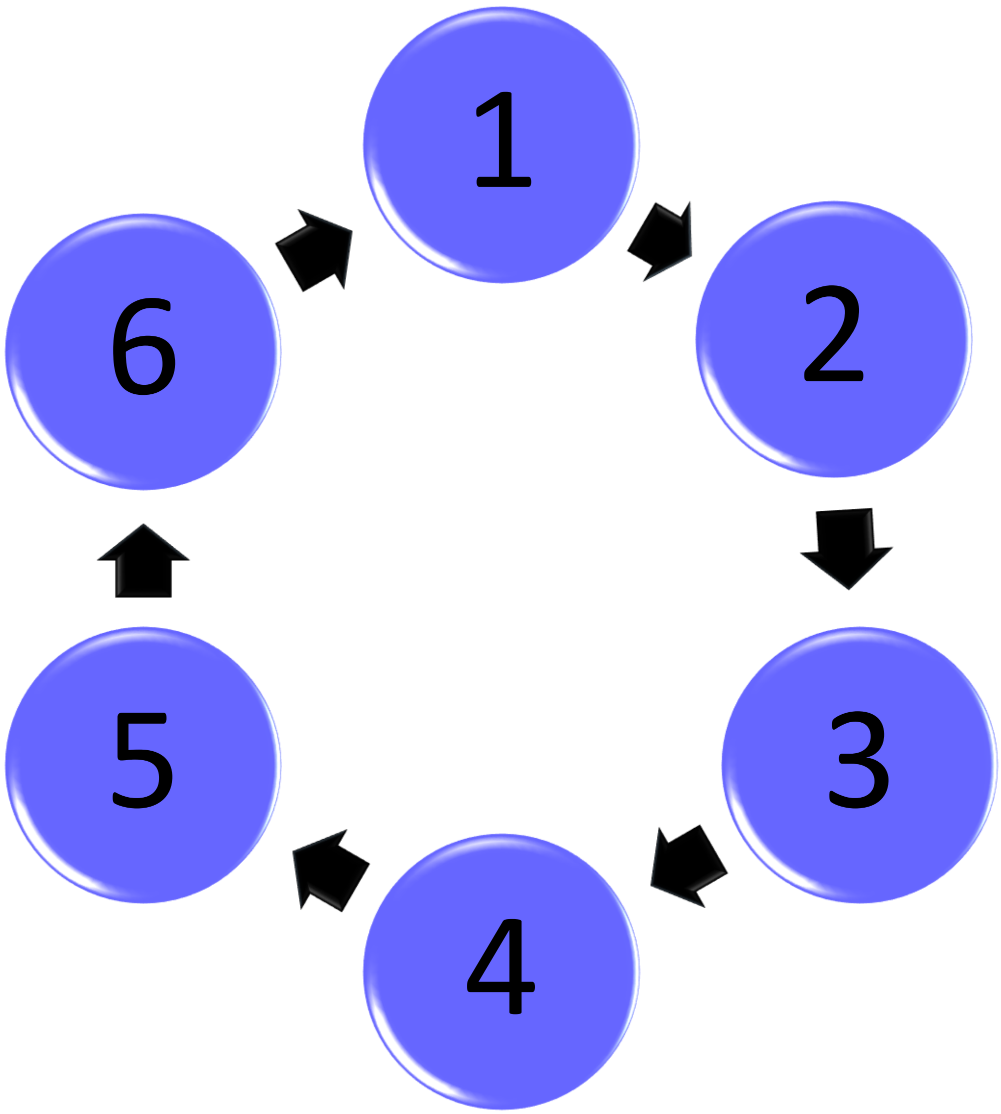
Low High

| ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

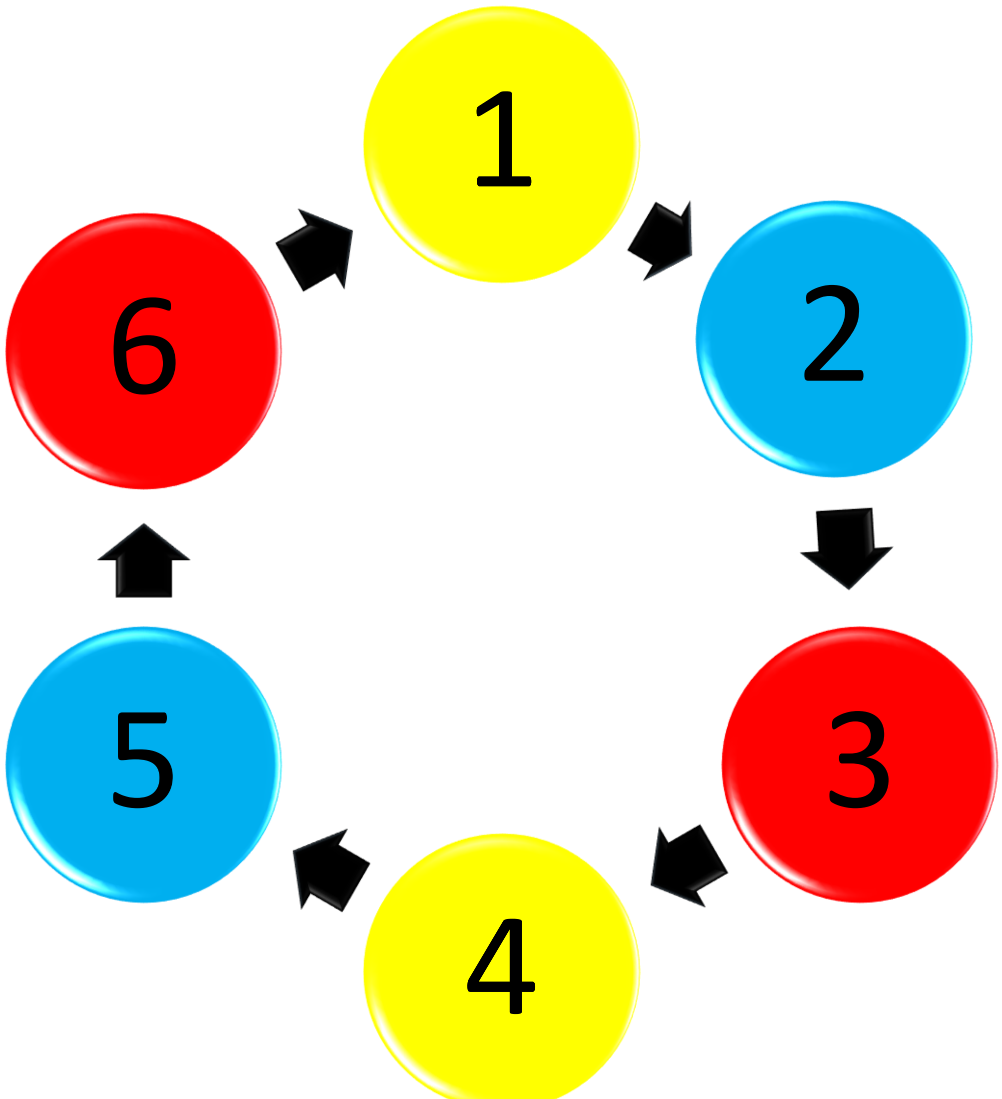
APPENDIX D

EXAMPLE OF COLOR SEQUENCE DOCUMENTS

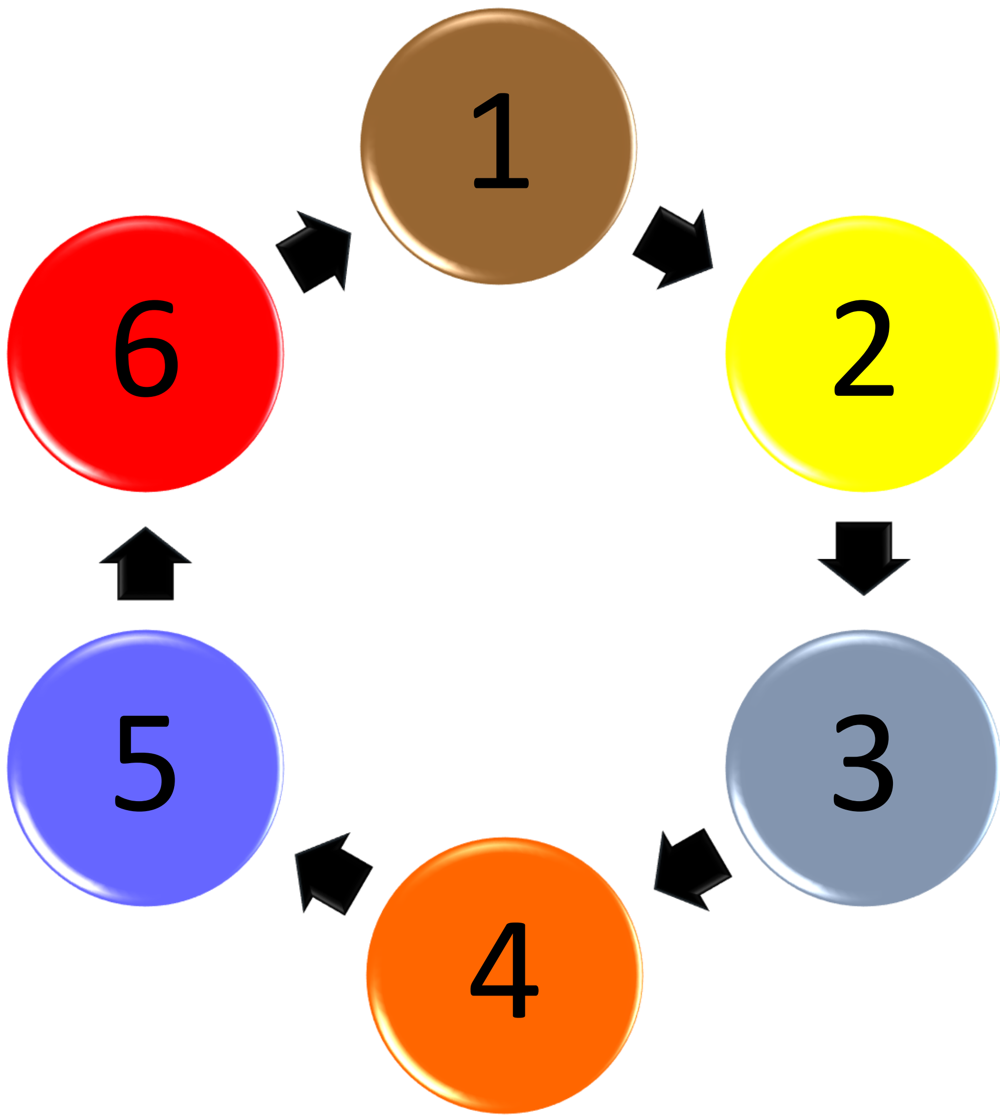
Low Load



Medium Load



High Load



APPENDIX E

SCRIPT

"Once again, I want to thank you for coming in today. During today's study, you will be doing a task that requires you to use hand-eye coordination in order to place rubber objects onto plastic pegs. Utilizing these graspers, you will pick up a rubber object with your non-dominant hand, transfer the rubber object to your dominant hand, and then you will place the rubber object on the opposite side of the pegboard. Prior to beginning the task, I will show you, for ten seconds, the order in which I want you to transfer the rings. After you transfer all six of the rings to the other side of the board, I will have you fill out this questionnaire.

"In a few moments you will have a chance to practice this task before the study begins. During this time, you will be able to ask me any questions that may come to mind. Keep in mind that your accuracy is more important than speed. Essentially, you want to transfer pegs as quickly as possible, while keeping errors to a minimum. Any questions?"

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